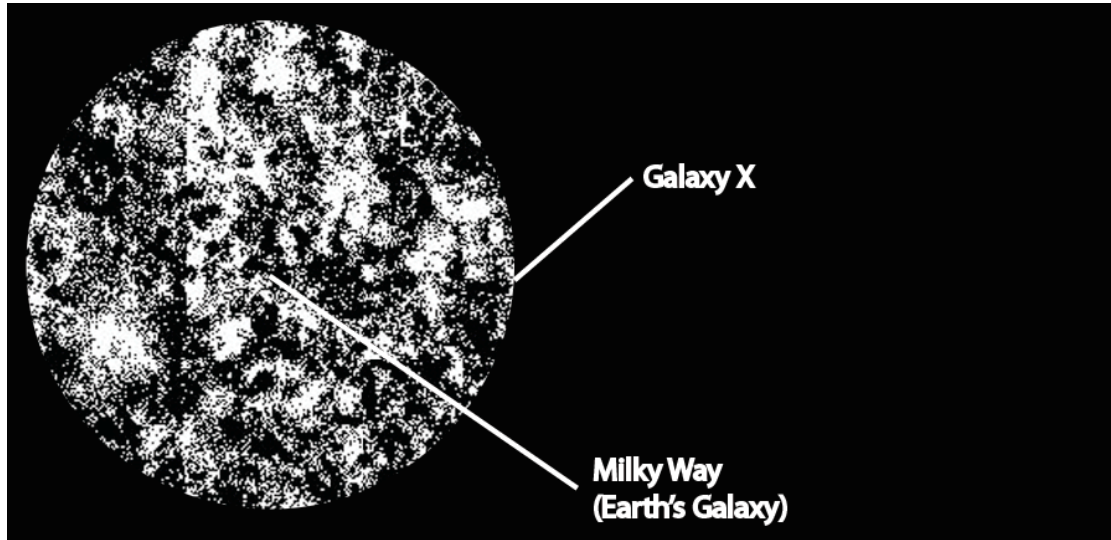


# Making Sense of the Universe and Expansion

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## Part I: The Observable Universe

Each dot in the picture below represents a galaxy. The Milky Way Galaxy is represented by the dot at the center of the picture. All of the galaxies inside the circle can be seen from Earth. The circumference of this circle defines what is called our *observable universe*. Any galaxy that exists outside the circle is so far away that its light has not had time to reach Earth and is therefore not part of our observable universe.



- 1) Do you think the galaxies we can see from Earth are the only galaxies in the *entire universe*? Explain your reasoning.
  
- 2) Draw a circle around Galaxy X that represents its *observable universe*.
  
- 3) Is the *observable universe* that you drew for Galaxy X different in size than the *observable universe* for the Earth? Explain your reasoning.

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4) Two students are talking about the *observable universe* for Galaxy X:

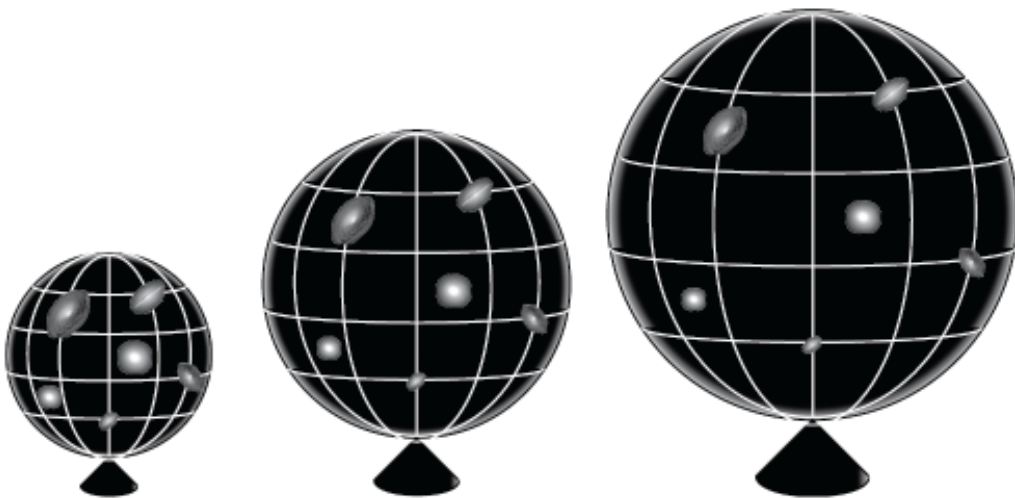
**Student 1:** *People living in Galaxy X have a strange view of the universe. When they look in one direction they see a bunch of galaxies, but when they look in the other direction all they see is empty space. Galaxy X must be at the edge of the universe since there's nothing but black, empty space beyond it. We're lucky we live at the center since we can see galaxies all the way out to the edge of the universe, no matter where we look.*

**Student 2:** *I think you're wrong. People living in Galaxy X would probably see a bunch of galaxies in every direction they look, but they can see some galaxies that we can't, just like we can see galaxies they can't. The observable universe for any galaxy should look similar to ours. I don't think we are at the center of the universe and I don't think Galaxy X is at the edge either.*

Do you agree or disagree with either or both of the students? Explain your reasoning.

### Part II: An Analogy for Expansion

One way to try to understand and envision the expansion of the Universe is by creating analogies that model the different aspects of our real expanding Universe. One way to model the expanding Universe is to use a “balloon” analogy. In this analogy, the space and time of the universe are modeled by the “surface” or “skin” of an expanding balloon. The *entire universe* only exists on the surface of the balloon. Light can only travel on the surface of the balloon.



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- 5) Do objects, light, or events in the *entire universe* also exist inside or outside of the balloon's surface in this analogy?
- 6) If you were to travel from galaxy to galaxy along the surface of the balloon, would you ever encounter an edge?
- 7) If you were to travel over the entire surface of the balloon universe, would you ever find a location that is the center of the *entire universe*?
- 8) Consider the following debate between two students about their answers to the previous questions:

**Student 1:** *Someone living on the surface of this balloon universe will definitely encounter an edge and a center. All they have to do is look from their location across the inside of the balloon to a location on the other side. The center of the inside of the balloon is the center of the universe, and the far side would be the edge of what they could see. So there's definitely a center and an edge to the universe in the balloon analogy.*

**Student 2:** *I think you misunderstand the analogy. The surface of the balloon is supposed to be the entire universe. The inside of the balloon isn't part of the universe and doesn't actually exist. You can't look through the inside of the balloon to the other side so there is no center in the middle or edge on the other side. In this analogy, people living in the balloon universe would never encounter a center or an edge.*

Do you agree or disagree with either or both of the students? Explain your reasoning.

- 9) The balloons on page 2 represent the universe at different times during its history. Draw an arrow underneath the balloons that points from the earliest time to the latest. Label the ends of the arrow with the words "earliest" and "latest."
- 10) Imagine you lived in a galaxy on the surface of the balloon. As the balloon expands, would all the other galaxies appear to move toward you or away from you?
- 11) Would your answers to the previous question be the same regardless of the galaxy in which you live, or would it change depending on the galaxy you inhabit?

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- 12) In this analogy, do galaxies move relative to one another because they are traveling across the surface of the balloon, or do they move relative to one another because the balloon is expanding?
- 13) The balloon analogy is a helpful way to think about expansion, but no analogy is perfect. Some aspects of the real universe are captured by this analogy while others are not. The evidence we now have about the real universe implies the following statements (a-f) are all true. For each of these statements, state whether it is accurately captured by the balloon analogy or not, and explain your reasoning.
- a) The real universe has no center.
  - b) The real universe has no edge.
  - c) The real universe is expanding.
  - d) The real universe is not round.
  - e) The real universe's expansion does not cause galaxies to change size.
  - f) The real universe is 4-dimensional (3 dimensions of space and 1 of time).